DARPA-USAF-USN
Joint Unmanned Combat Air Systems

Intelligent System Capabilities and Operator Decision Aides

(Combat UAV 2004 Presentation)

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Presentation Overview

- **Background**
- **Decision Aiding System (DAS)**
- **Designing a DAS**
- **Results**
- **Summary**

Types of Intelligent Systems

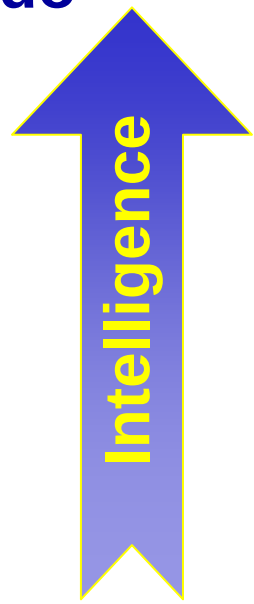
Coaches **try to make you better at what you do**

DAS

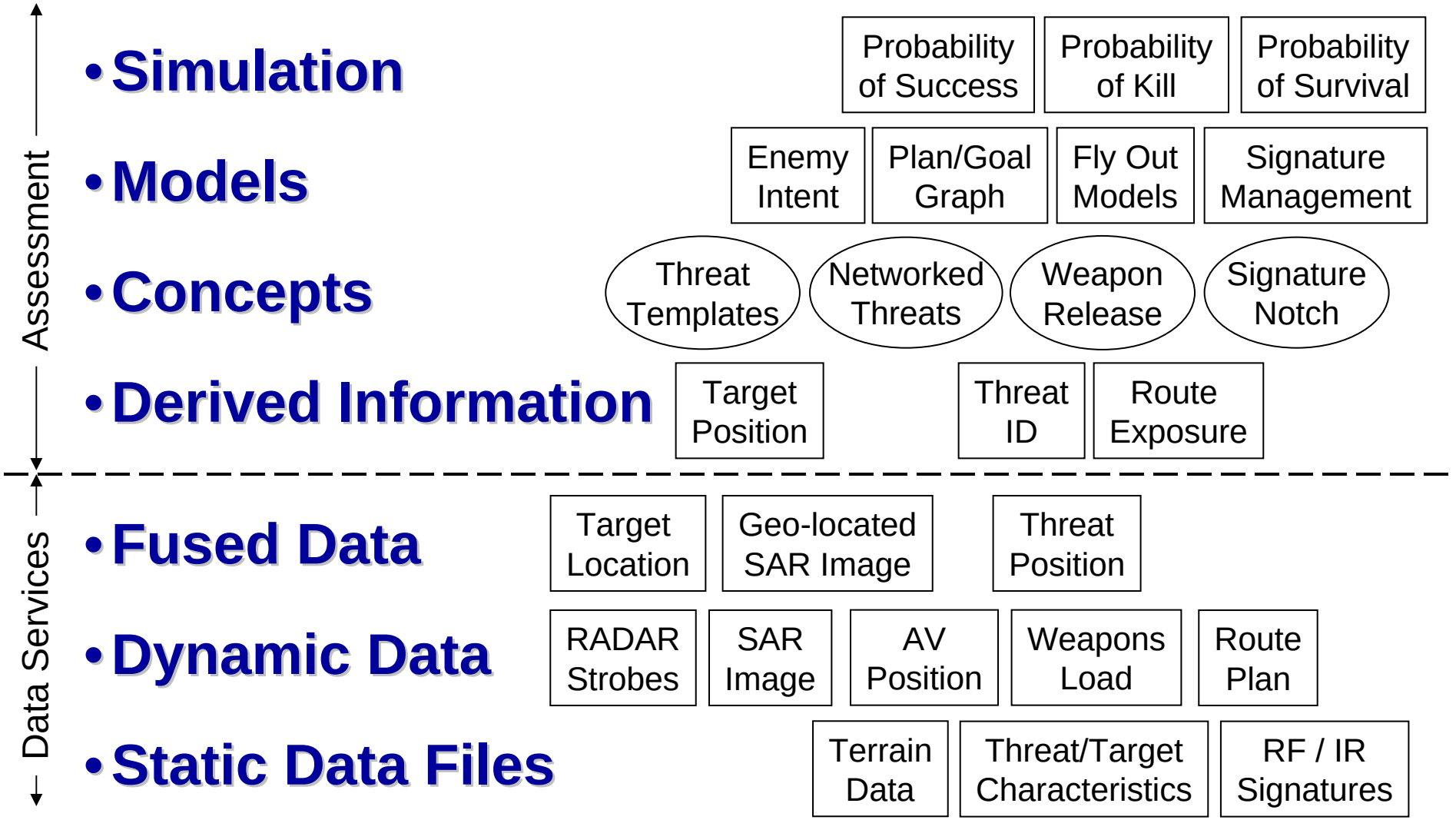
Associates **automatically help with tasks**

Assistants **do what you ask them to do**

Experts **do what they know how to do**

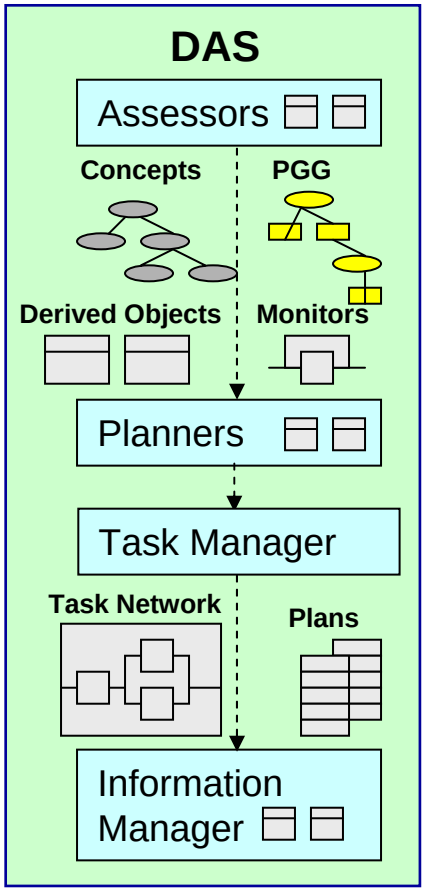


Understanding Built on Data

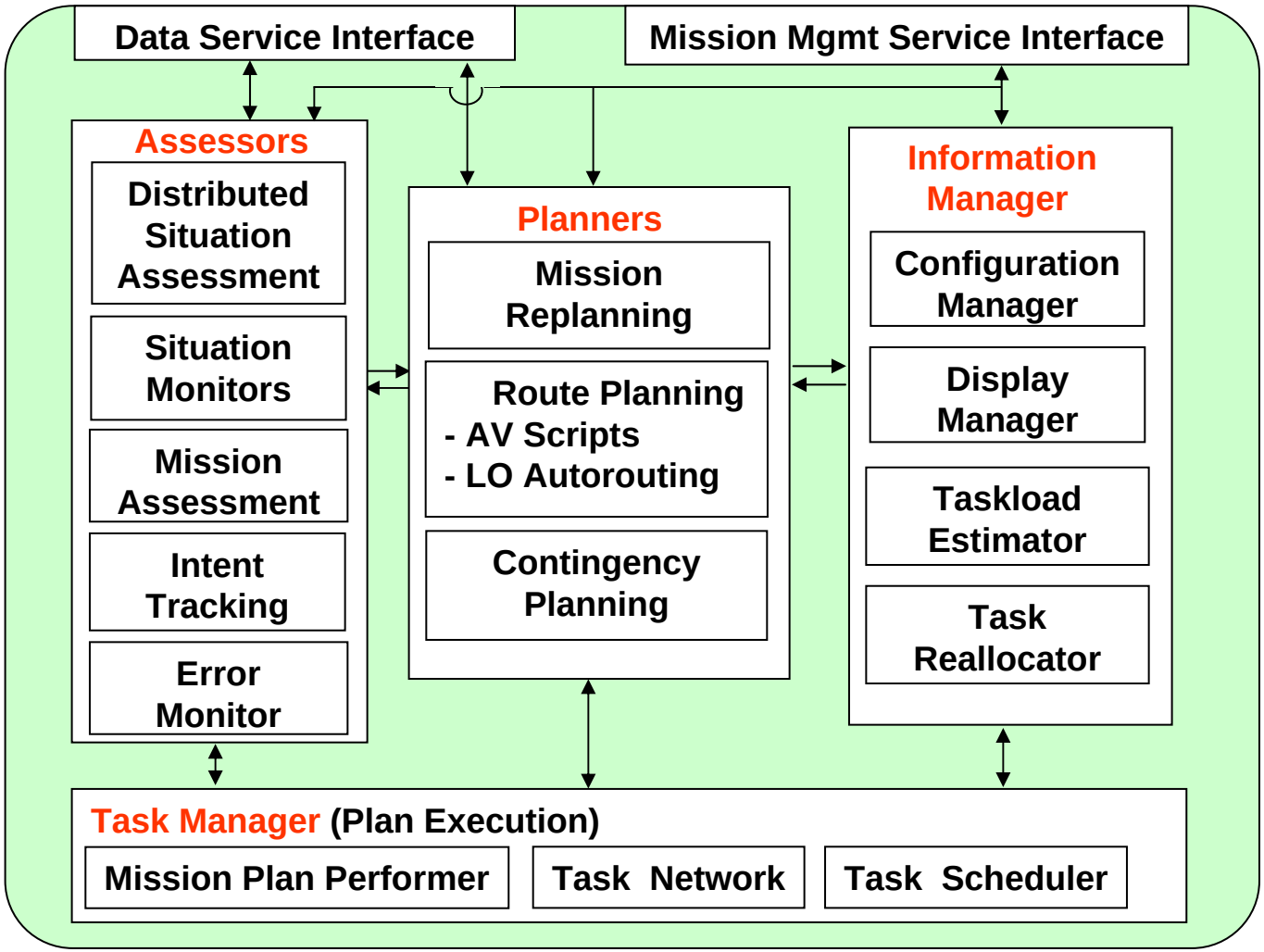


Decision Aiding System (DAS) Functionality Overview

Assessors	Planners	Task Manager	Information Manager
Monitor mission. **Detect new threats.** **Assess route impact.** **Trigger replanning.** **Monitor mission plans.** **Monitor status.**	**Provide weapon allocation to targets.** **Evaluates mission plan alternatives with different defining parameters.** • Type (ATK, SAR, etc.) • Target • Rejoin point • Weapon type/ number **Recommends new mission plan.** **Operator can apply or cancel recommended plan.**	**Task Network equivalent to a manager's PERT chart to coordinate activities.** **Temporal task model of operator and computer tasks.** **Tasks prioritized by task importance and deadline.** **Operator task drives displays via information requirements.** **Computer tasks drive automation.**	**Bring up displays or specific pages.** **Pan/zoom about proposed mission plans.** **Bring up weapon pairing/LAR ymbols.** **De-clutter unwanted symbols.** **Locate secondary window text in open corners.** **Prioritize alerts.** **Reallocate tasks.**



Decision Aiding Notional Software Architecture



Knowledge Engineering Process

Step	Product	Tool
Identification of knowledge requirements	**Requirements Document, Knowledge Engineering Plan**	**Requirements Engineering tool such as DOORS**
Production of the domain ontology for the domain of interest	**Domain Ontology**	**Relational Database**
Production of system knowledge at an intermediate level of representation	**Intermediate Representation Forms- Contains activities such as Plans, Goals, Graphs, and Tasks**	**Integrated Knowledge Environment (IKE)**
Conversion of this intermediate level representation to operational knowledge	**Knowledge Base File containing the Operational Knowledge Representation**	**IKE**
Testing of this knowledge to validate it	**Validated Knowledge**	**Test Plans, Models, and Simulations**

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Domain Ontology (Definition)

do·main: a sphere of knowledge, influence, or activity

on·tol·o·gy: a particular theory about the nature of being or the kinds of existents

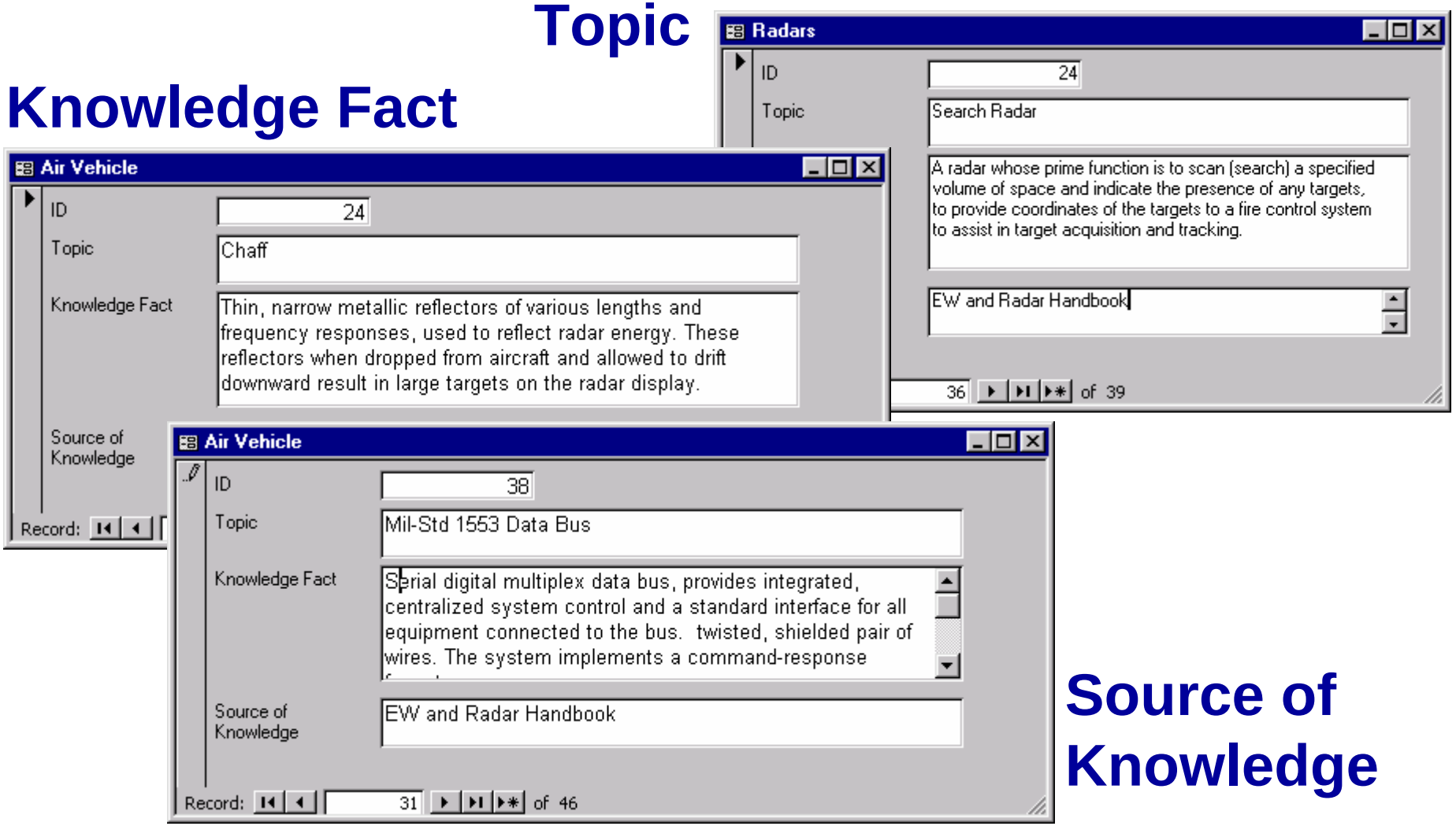
"What things exist in your sphere of knowledge"

Unmanned Combat Air Vehicle Flight Operations

Domain Ontology (Knowledge Categories)

Air Vehicle	*Physical Description*
Airspace	*Zones and Areas*
Aviation	*Aircraft Operations and Performance*
Communications	*Radios and IFF*
Formulary	*Mathematical Formulas*
Mapping, Charting, Geodesy and Imagery	*Navigation*
Mission Planning	*Flight Planning plus Target Engagement*
Radar	*ESM and SAR*
Roles and Missions	*Aircraft Roles and Combat Missions*
Weapons	*Air-to-Surface and Surface-to-Air*

Relational Database Organizes Domain Ontology



Domain Ontology Representation (Example)

Major Area	Minor Area	Topic	Knowledge Fact	Knowledge Source
Intelligence	Source	Electronic Order of Battle (EOB)	The identification, location, and disposition of electronic systems of a military organization.	Space and Electronic Warfare Glossary
Intelligence	Targeting	Target	A geographical area, complex, or installation planned for capture or destruction by military forces. An area designated and numbered for future firing. A thing or place to be aimed at or hit.	DoD Glossary
Mission Planning	N/A	Desired Mean Point of Impact (DMPI)	The planned point whose coordinates are the arithmetic means of the coordinates of separate points of impact of a finite number of projectiles fired or released at the same aiming point under a given set of conditions.	Military Dictionary
Mission Planning	N/A	Rules of Engagement (ROE)	Directives issued by competent military authority which specify circumstances and limitations under which US forces will initiate or continue combat engagement with other forces.	DoD Glossary

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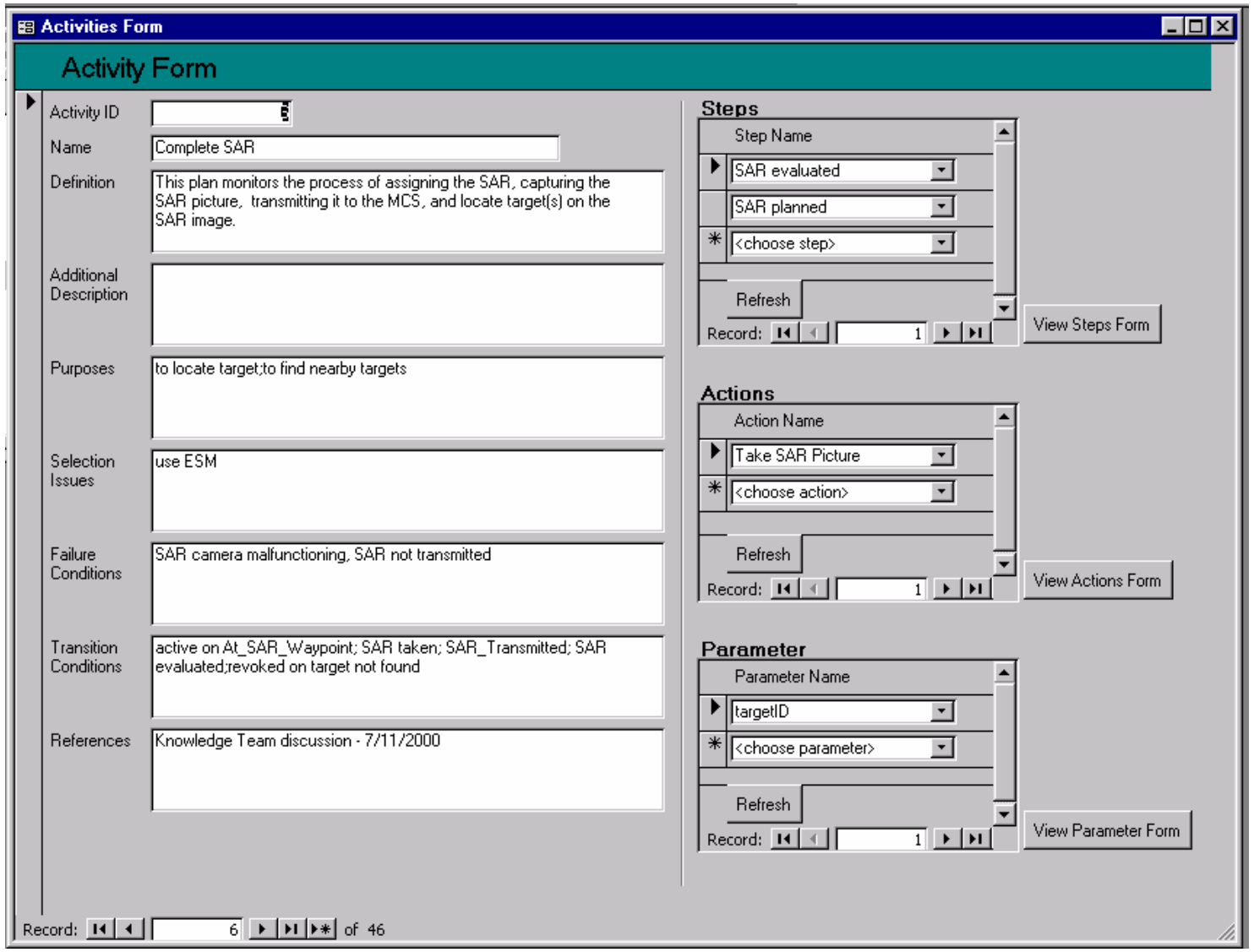
Intermediate Knowledge Representation



Integrated Knowledge Environment (IKE)

Intermediate Knowledge Representation

Step

Name	*Eligible Target Handled.*
Description	*This goal marks event "new emitter detected, ready to be rank ordered, prioritized, and assigned to a UCAV."*
Preconditions	*Emitter must be in a kill box and on the Electronic Order of Battle (EOB). Air Vehicle and weapons available.*
Desired Outcomes	*Emitter will be rank ordered.* *Emitter may be prioritized and assigned.*
Other effects	*Attack maneuvers may follow.*
Recurrence	*Per new emitter detection.*
Failure Conditions	*None.*

Intermediate Knowledge Representation

Activity

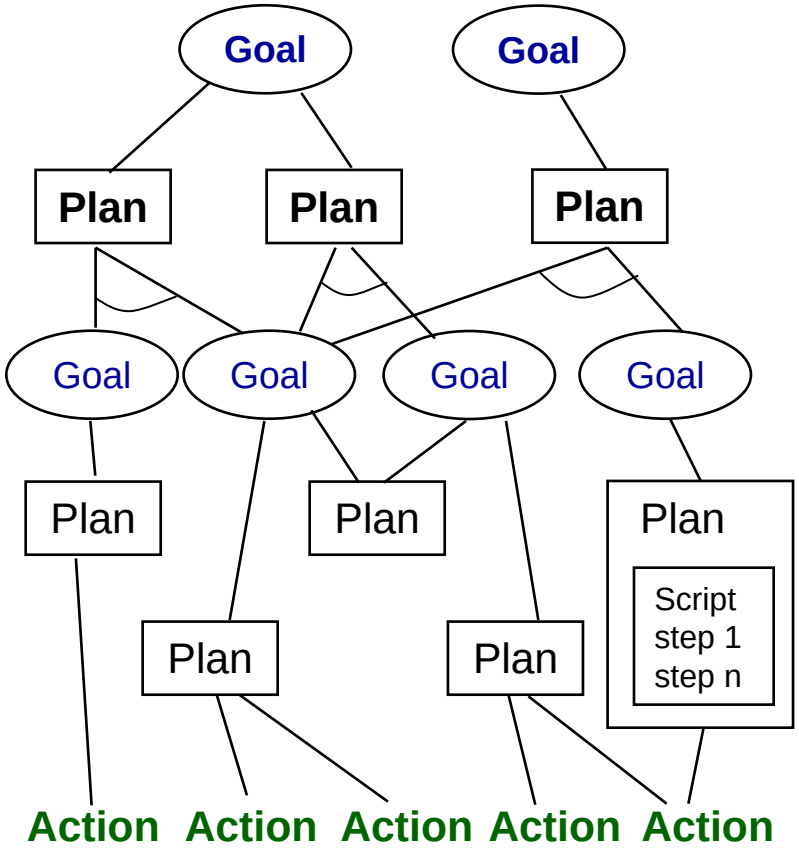
Name	*Recommend Plan.*
Definition	*Evaluate eligible target, Rules of Engagement (ROE), air vehicle state and recommend appropriate script.*
Purposes	*Initiate the mission planning process.*
Selection Issues	*None.*
Failure Conditions	*None.*
Transition Conditions	*None.*

Intermediate Knowledge Representation

Action

Name	*Call Mission Planner.*
Definition	*Send recommended script.*
Desired Outcome	*Operator accepted, populated script. Eligible target promoted to target upon Operator acceptance.*
Preconditions	*None.*
Failure Issues	*Task network communication failure.*
Prohibitions	*None.*

Plan-Goal Graphs Describe System Purposes

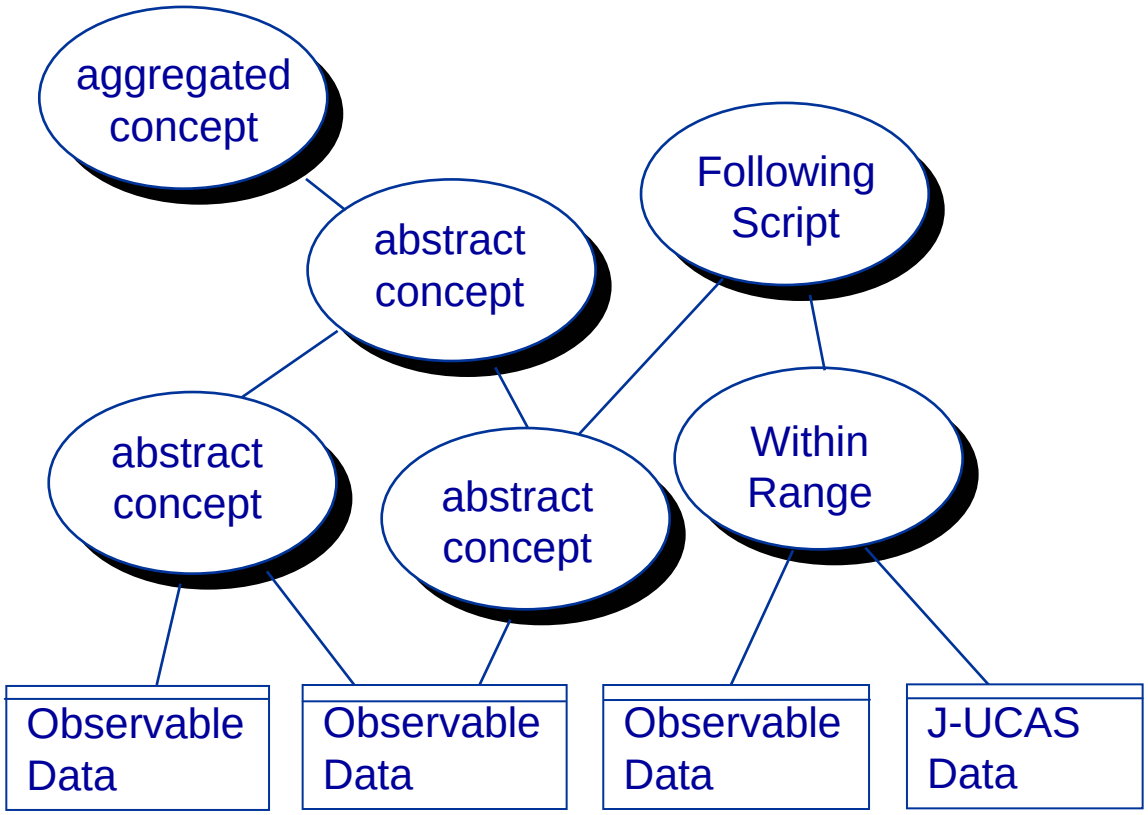


INTENT

- **The Plan Goal Graph**
  - Models operator intent

- Plan-Goal Graph (PGG) - a hierarchical decomposition of the mission.
- Rectangles represent plans which indicate “what” the operator is doing.
- Ellipses represent goals or “why” the operator is executing each plan.
- Plan requires all goals to be satisfied (an “and” node); goal requires only one plan to be successful (an “or” node).
- Plan may contain a script: a sequence of simple steps.
- Lowest level of decomposition (actions) represent primitive manipulations.
- Links contain knowledge in the form of constraints (e.g. within weapons range).

Concept Graphs Describe the Situation

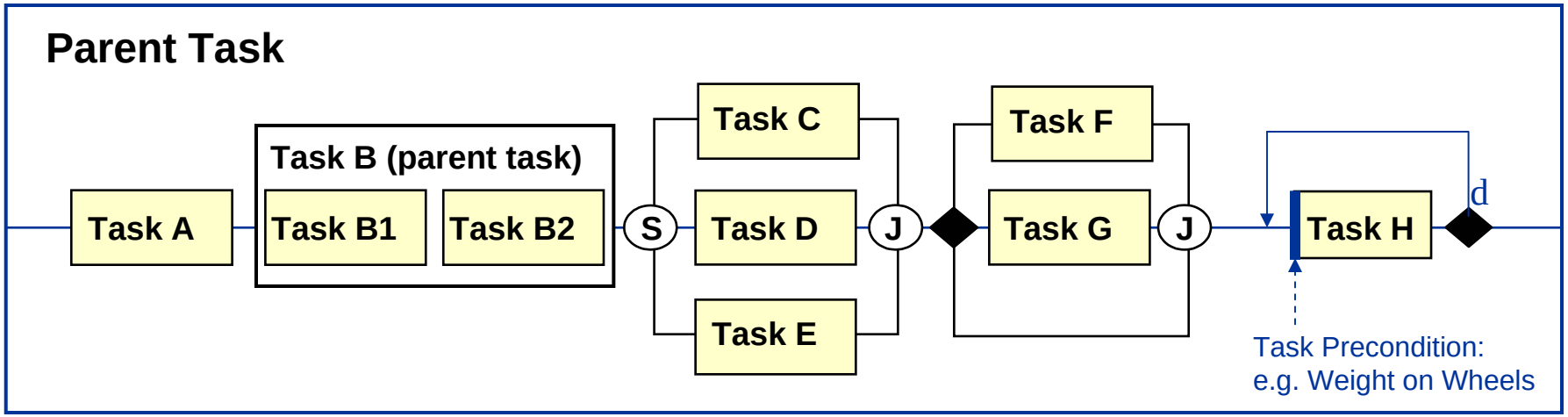


- Directed acyclic graph
- Increasing in abstraction and aggregation
- Links indicate dependencies
- Value propagation is dependency-directed

FACT

- **The Concept Graph**
  - Represents real world state

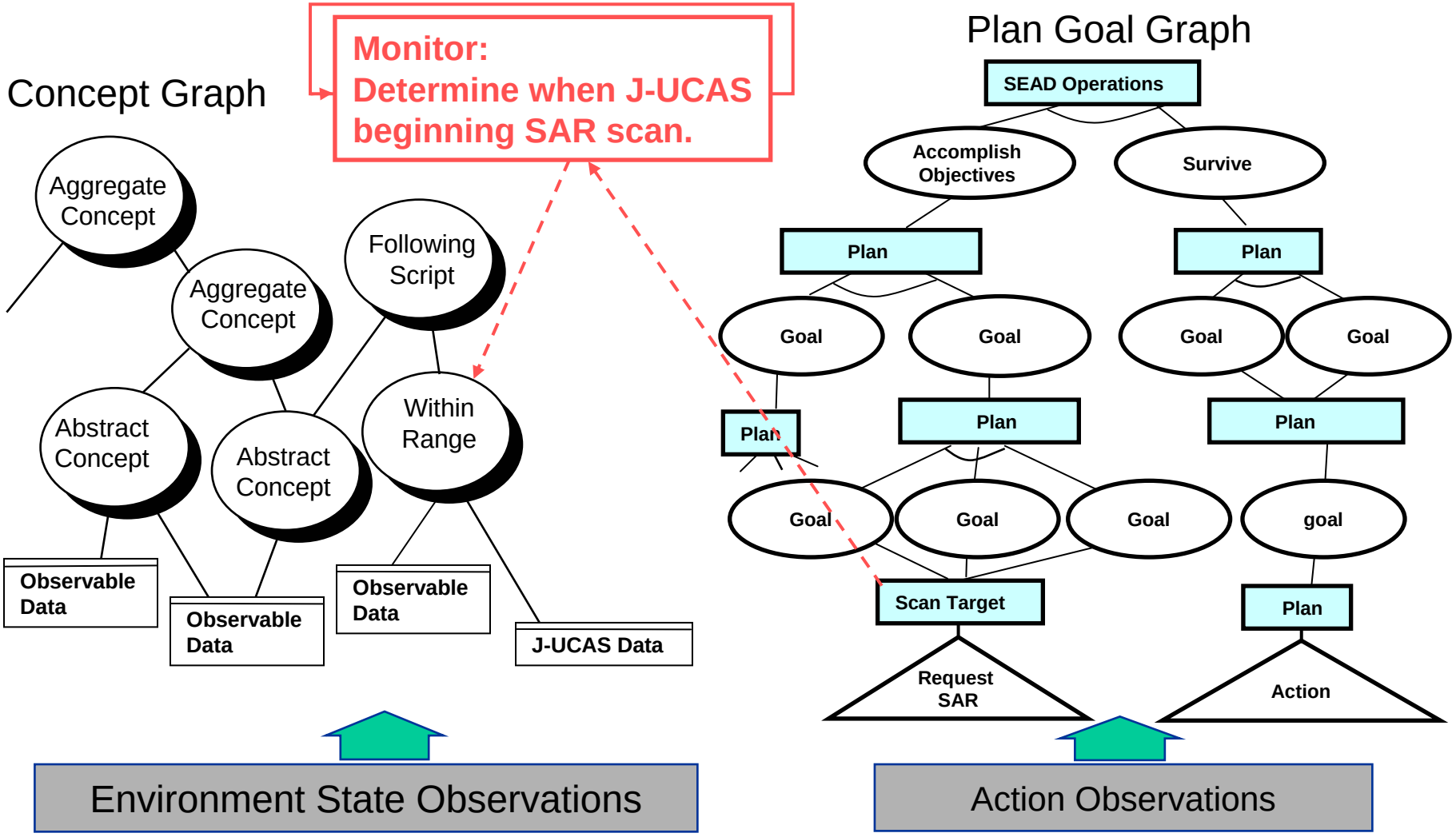
Task Network Node Types



Task Network Similar to Management PERT Chart

- Represents computer tasks (1 - 100 mseconds)
- Represents operator tasks (1- 60 seconds)
- Network Topology represent task dependencies
- Task parameters include task importance and deadline

Monitors Link the Concept Graph and PGG



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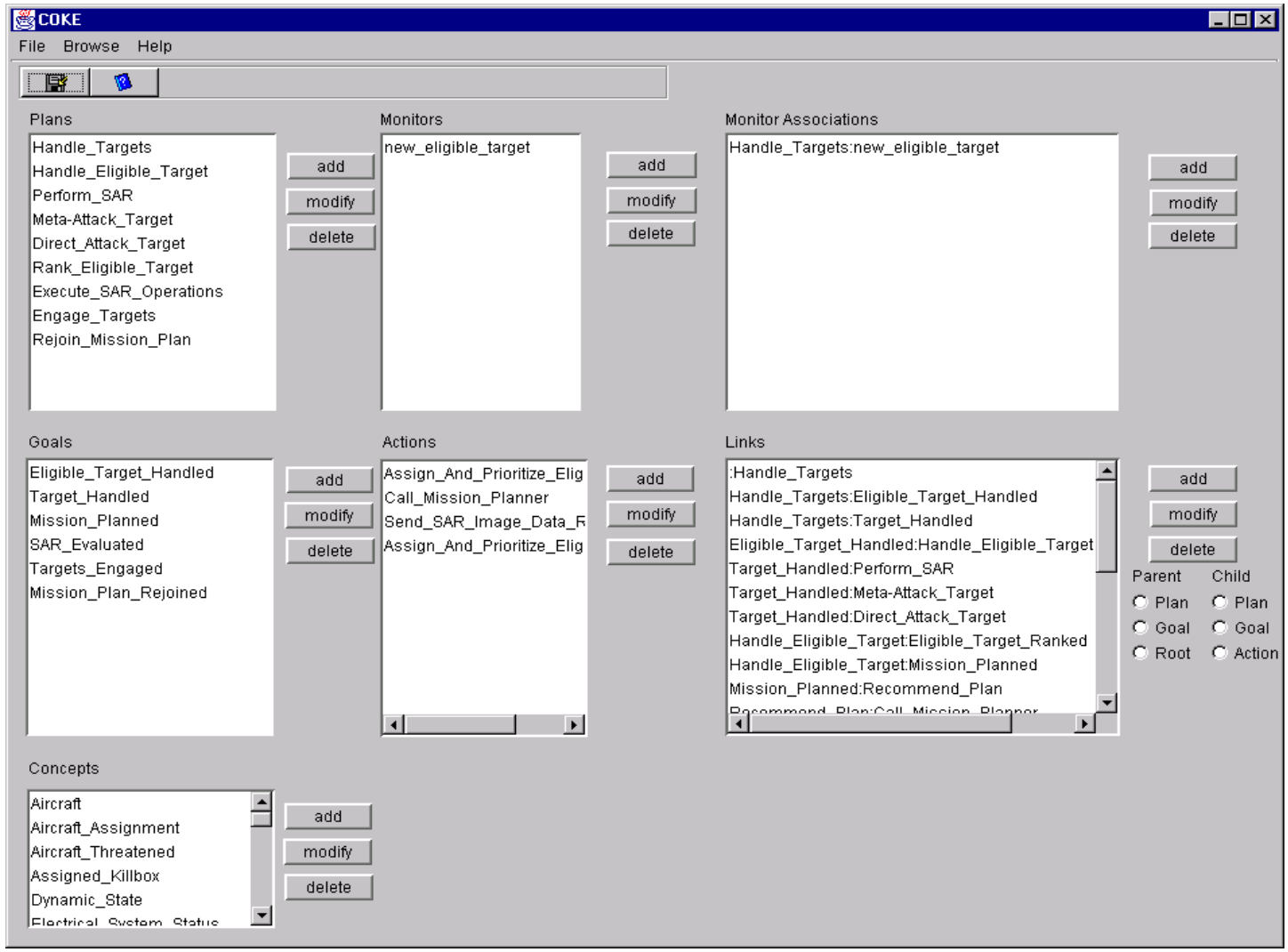
Operational Knowledge Representation



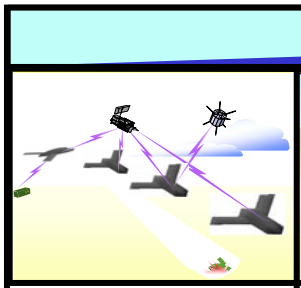
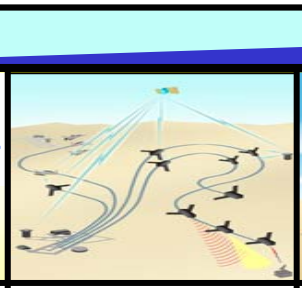
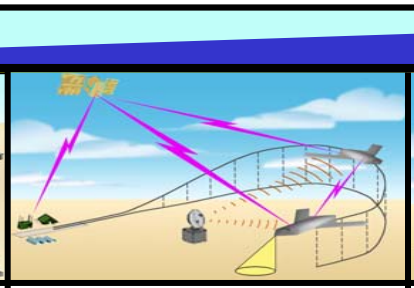
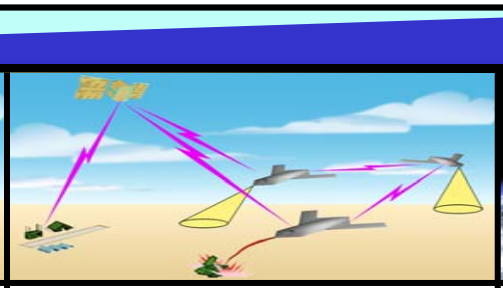
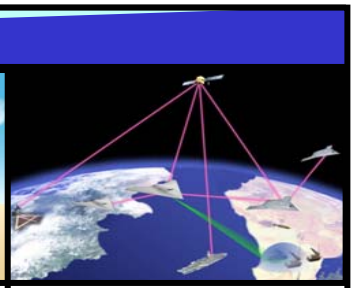
Integrated Knowledge Environment (IKE)

Knowledge Base (kb) File

```
// ---------------------------------------------------------------
MONITOR:

  Monitor_Name: At_SAR_Waypoint
  //This monitor fires when the SAR waypoint is the next waypoint
  //and the distance is less than 750 meters.

  Concept: Nominal_Trajectoty_Status

  Attribute: actor VAR aircraftID
  Attribute: waypoint VAR nextWaypointNum

  BEGIN_CONSTRAINT
    Operator: LESSER
    Left: context DOUBLE Nominal_Trajectory_Status:actor:distanceToNext
    Right: literal DOUBLE 750.0
  END_CONSTRAINT

  BEGIN_CONSTRAINT
    Operator: EQUAL
    Left: context INT Nominal_Trajectory_Status:actor:nextWaypointNum
    Right: value_list INT waypoint
  END_CONSTRAINT

END_MONITOR

// ---------------------------------------------------------------
```

Intelligent System Capability Development

0 — Incremental Build-Up of Functionality → 100 %

Block 1	Block 2	Block 3	Block 4	Future Operational System

Decision Aiding System (DAS)

Operator Interface Software

Mission Planning → Controls & Displays

Data Server

Assessors → Planners / Executors → Information Manager

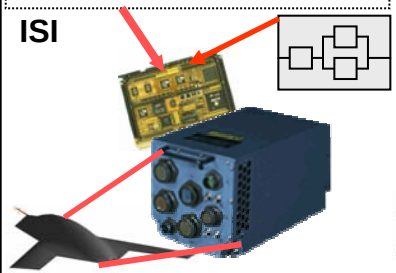
Plan Goal Graph (PGG) | Concepts | Task Network

Onboard Intelligent Software Infrastructure (ISI)

Data Server

Assessors → Planners/ Executors → Information Manager

ISI



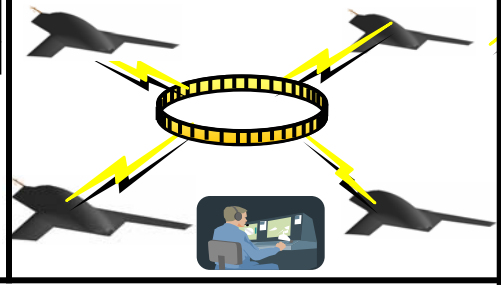
Supervised Intelligent Operations

Multi-Air Vehicle (AV) Cooperation

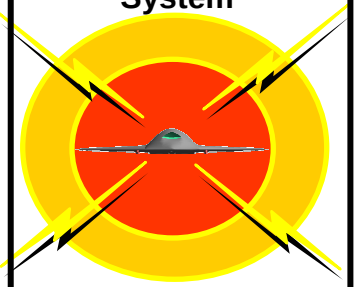
Multi-AV Cooperative Behavior with Manned Platforms

ISI

Intelligent Application Software



Battle-Aware Intelligent System



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